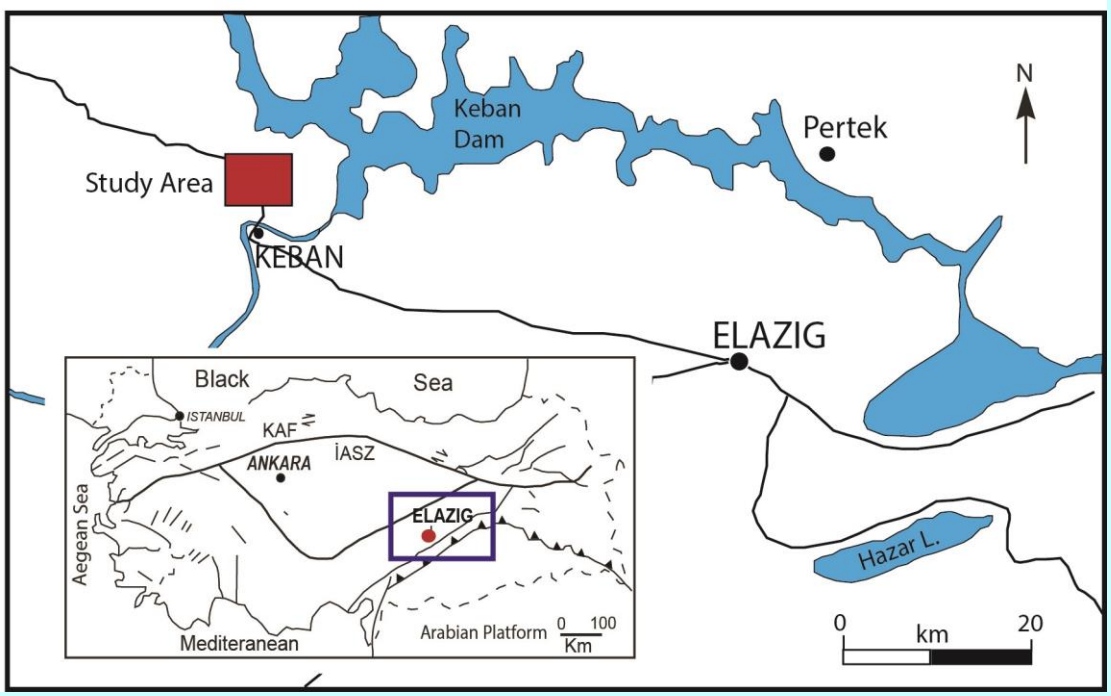
Mineralogy and Petrography of the Keban Pb-Zn-(Cu) Skarn Deposit, Elazig, Eastern Turkey

Ece Kirat[1], Halim Mutlu[1]
[1]Ankara University



The polymetallic Keban province is located in the Eastern Taurus orogenic belt and historically experienced mining activities, the Hittites dating back to 2000 BCE. The Eastern Taurus orogenic belt is a part of the Alpine-Himalayan metallogenic belt and is an important province among other mining regions in Turkey. The area contains volcanogenic massive sulphides (VMS), hydrothermal veins, epithermal, Fe-oxide-Cu-Au (IOCG), skarn and porphyry type deposits.

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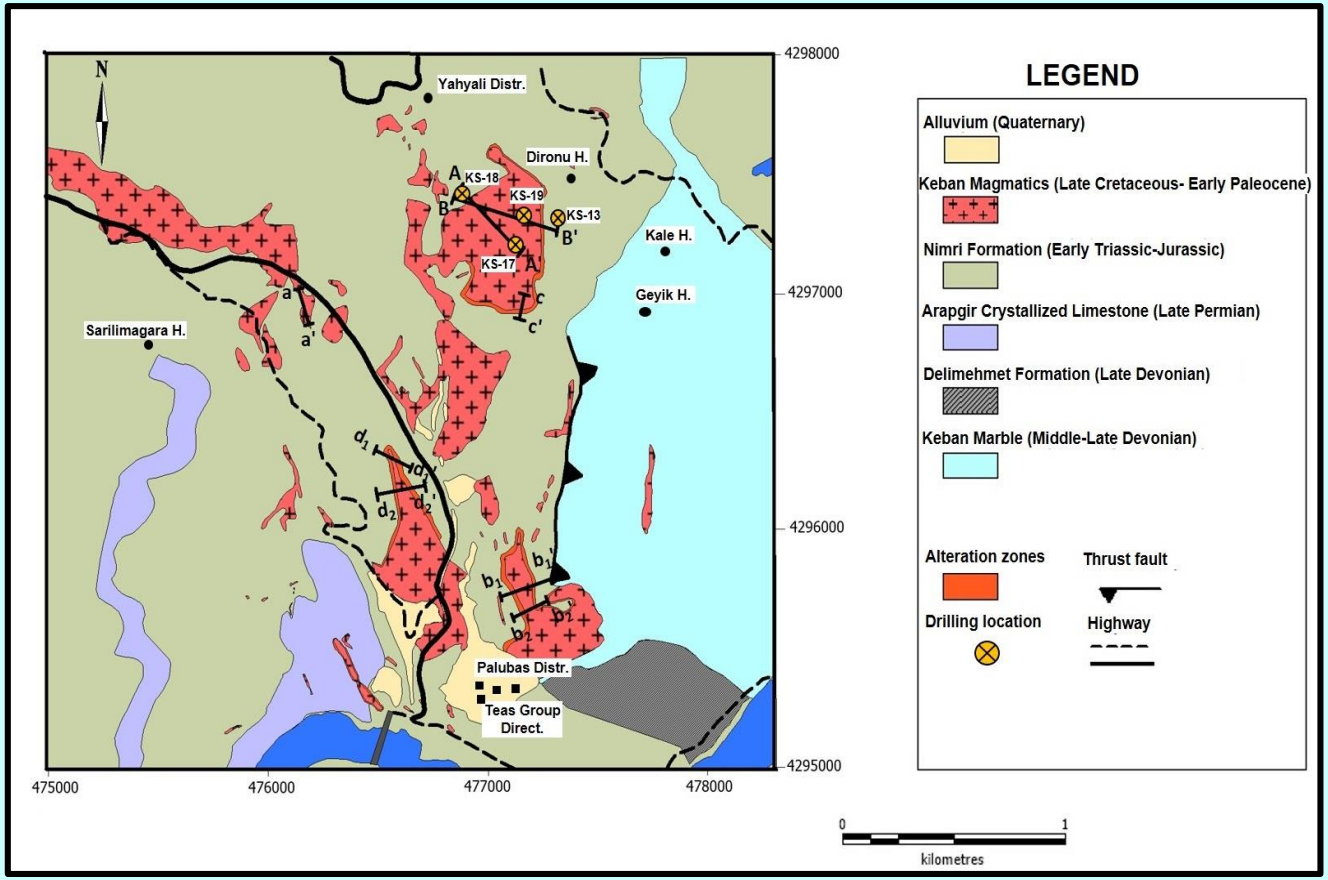
1. Regional Geology



The Keban skarn deposit in the Elazig region was formed at the contact between the Permo-Triassic metamorphics and the Late Cretaceous plutonic rocks. The Late Cretaceous Keban Magmatics, emplaced as dyke/sill and stock-like large apophysis, intrudes to the meta-clastic/carbonate rocks of the Early Triassic/Jurassic Nimri Formation and as a result, contact metasomatic skarn zones and mineralization were formed along its contacts.

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2. Petrograpy of the Keban Plutonic Rocks

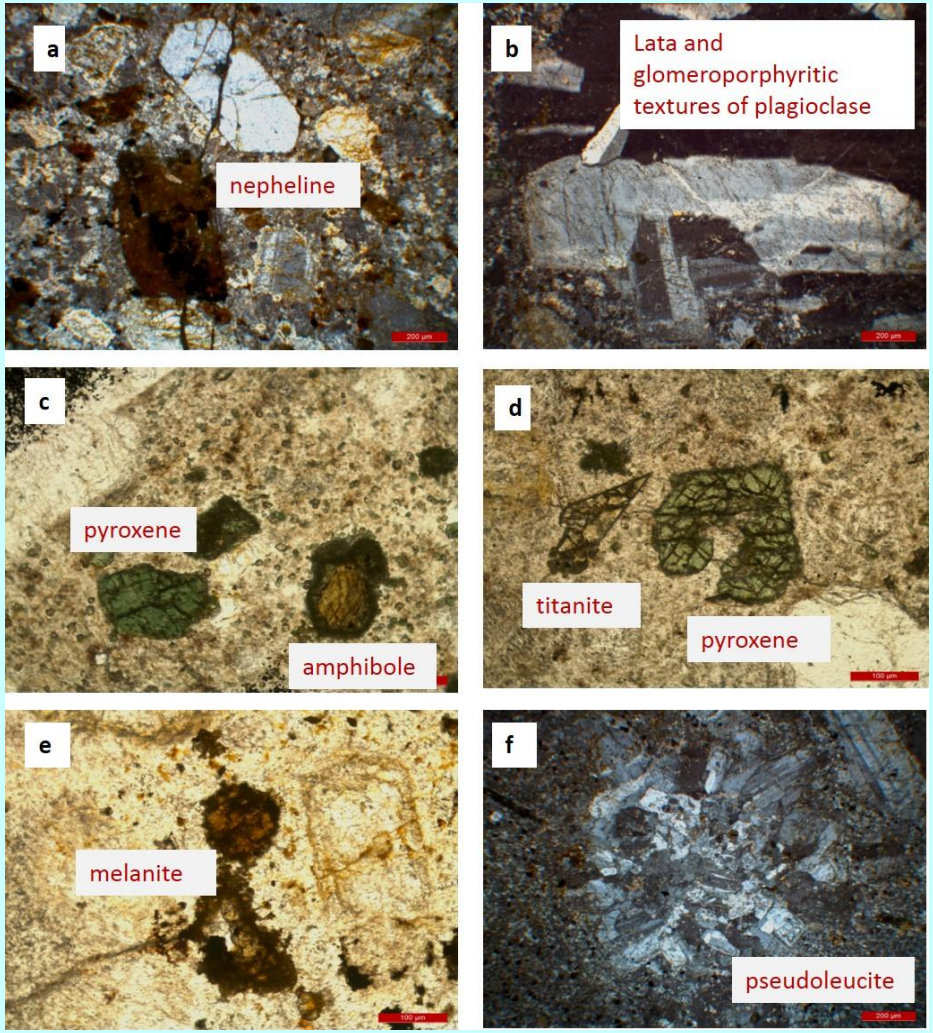

Figure 3.

Keban plutonic rocks hosting foid syenite porphyry and nepheline syenite are of holocrystalline hipidiomorph porphyritic texture including large nepheline and plagioclase phenocrystals.
Euhedral nepheline has porphyritic texture (Figure 3a).
Plagioclase has zonned, poiclitic, lata and glomeroporphiric textures (Figure 3b).
Sericite and clay alteration are very common in alkali feldspar.
Amphibole minerals are equally-platy-shaped and have strong pleochroism. Some samples show cleavage in two directions (Figure 3c).
Plate-shaped pyroxenes have a light green color and cleavage in two directions in PPL (plane polarized light) (Figure 3c-d).
Titanite with clear cleavage has a strong relief (Figure 3d).
Melanite, which is one of the garnet minerals, is observed as euhedral crystals (Figure 3e).
Pseudoleucite has first order interference color and low relief (Figure 3f).

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2. Petrograpy of the Keban Metamorphics

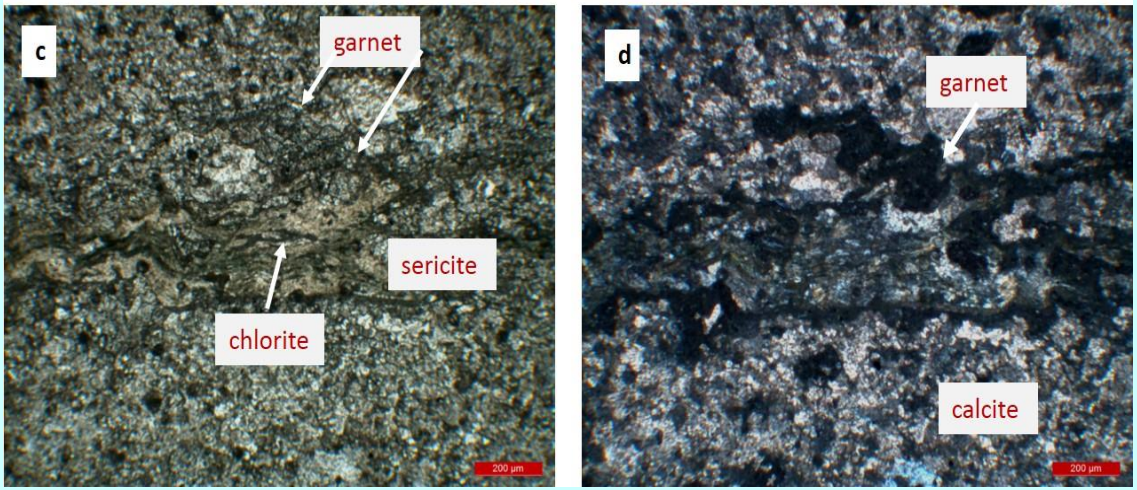

Figure 4.

2.1 Calc-shist (Nimri Formation)

Calcschist is composed of calcite, quartz, sericite, alkali feldspar, garnet, chlorite, epidote, opaque minerals and organic material (Figure 4a). It has granolepidoblastic and lepidoblastic textures. Calcite, which is the main minerals, lies parallel to the schistosity and has granoblastic crystals. Small to medium sized garnet has isotropic feature in XPL (crossed polar light) (Figure 4b)

2.2 Keban Marble

Calcite minerals forming the Keban marble show granoblastic texture (Figure 5a), coarse crystals and have 4th order of interference colours with pressure twinning (Figure 5b).

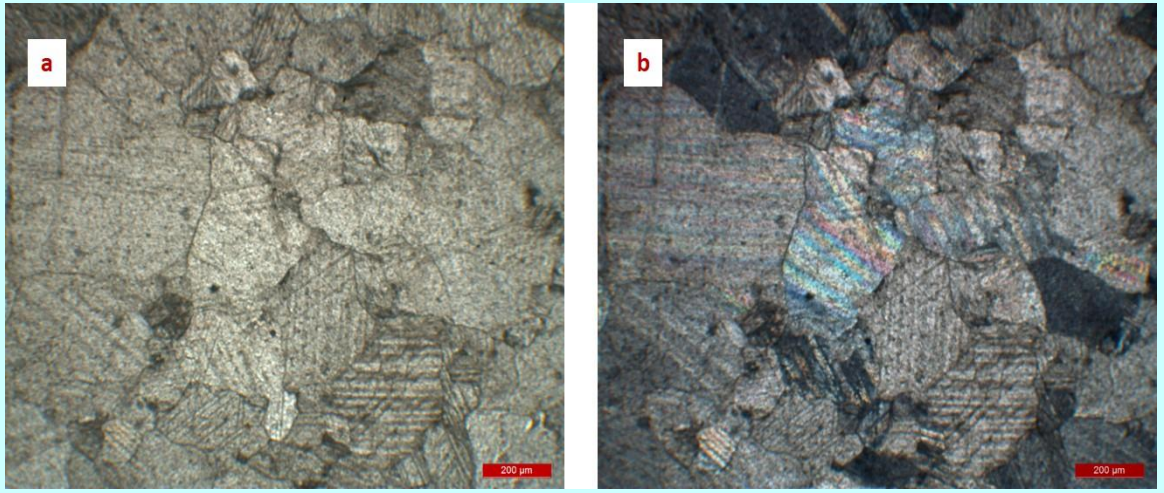

Figure 5.

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3. Petrography of skarn minerals

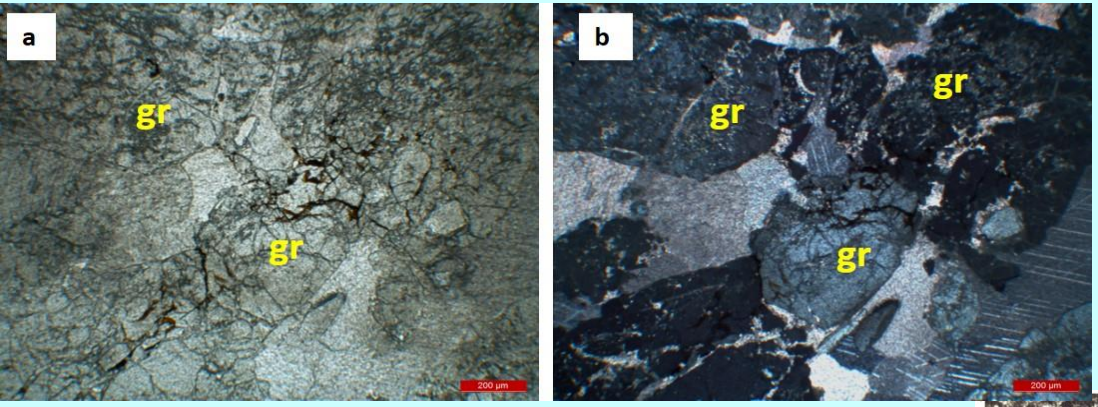

Figure 6.

The endoskarn zone consists of plagioclase, pyroxene and garnet minerals, whilst the exoskarn zone includes garnet, pyroxene and vesuvianite minerals.

Garnet and pyroxene-rich skarn formed in the early (prograde) stage of skarnization whereas epidote, allanite, chlorite, tremolite, phlogopite, muscovite, calcite, quartz and fluorite are typical minerals of the retrograde stage.

Euhedral garnet minerals have high relief (Figure 6a) and isotropy whereas some grossular minerals show anisotropye due to Al enrichment (Figure 6b). With the help of Raman spectroscopy, hessonite (grossular) is determined (Figure 7). Garnet in endoskarn is of andradite-grossular composition whereas those of distal exoskarn are composed of andradite type..

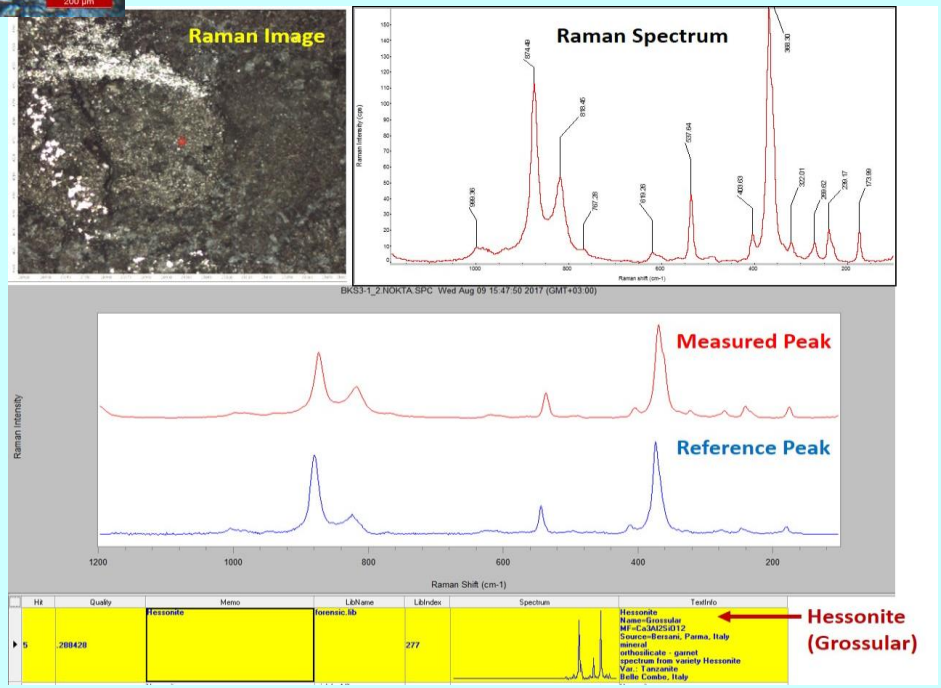

Figure 7.

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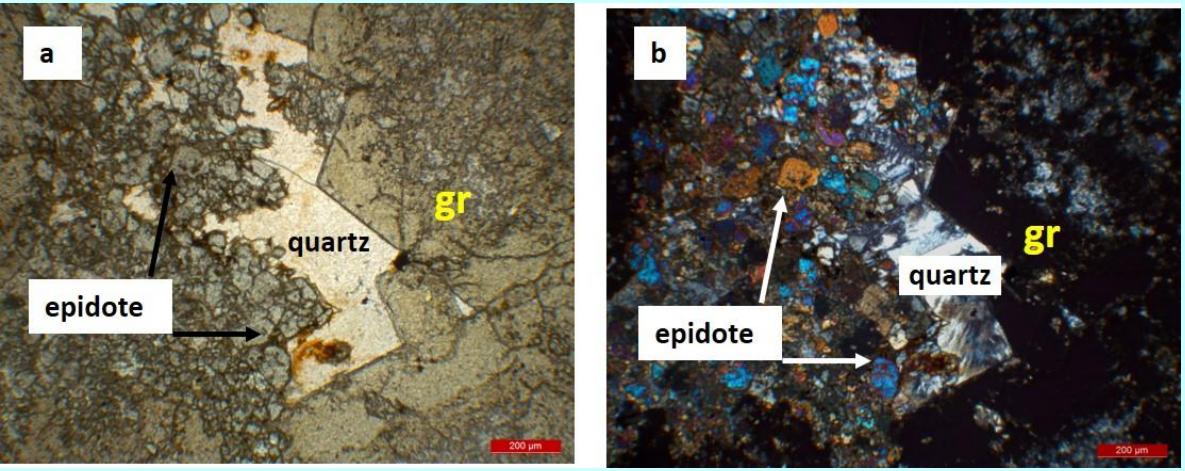

Figure 8.

Andradite shows zoning due to invasion of Fe^{+3}-bearing solutions in the retrograde stage. It is accompanied by epidote and quartz (Figure 8a-b). Raman spectroscopy indicates that andradite is replaced by calcite (Figure 9).

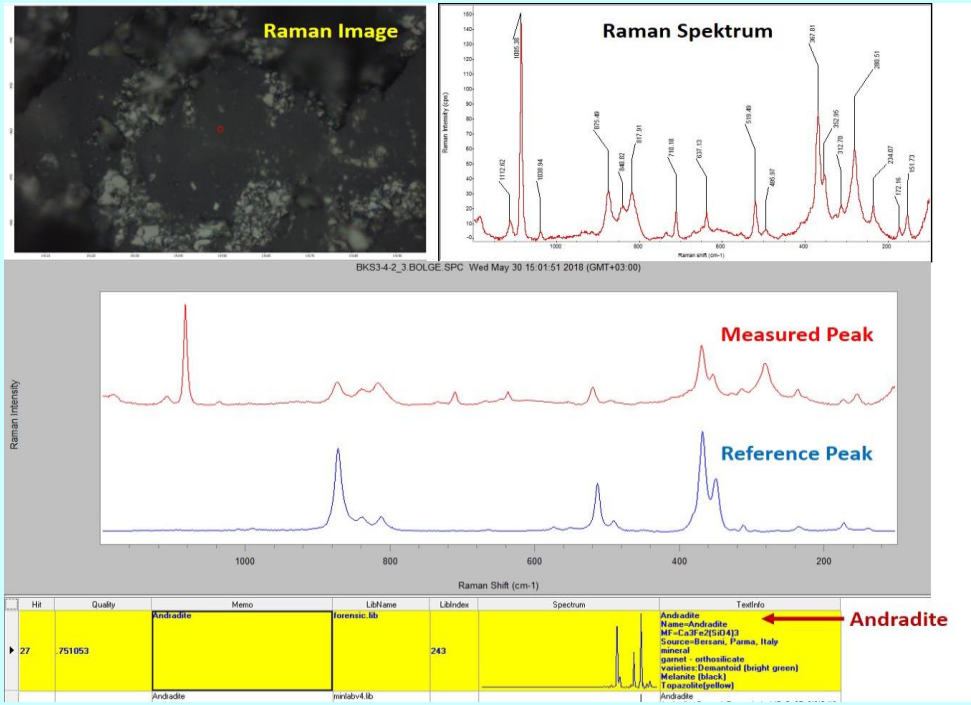

Figure 9.

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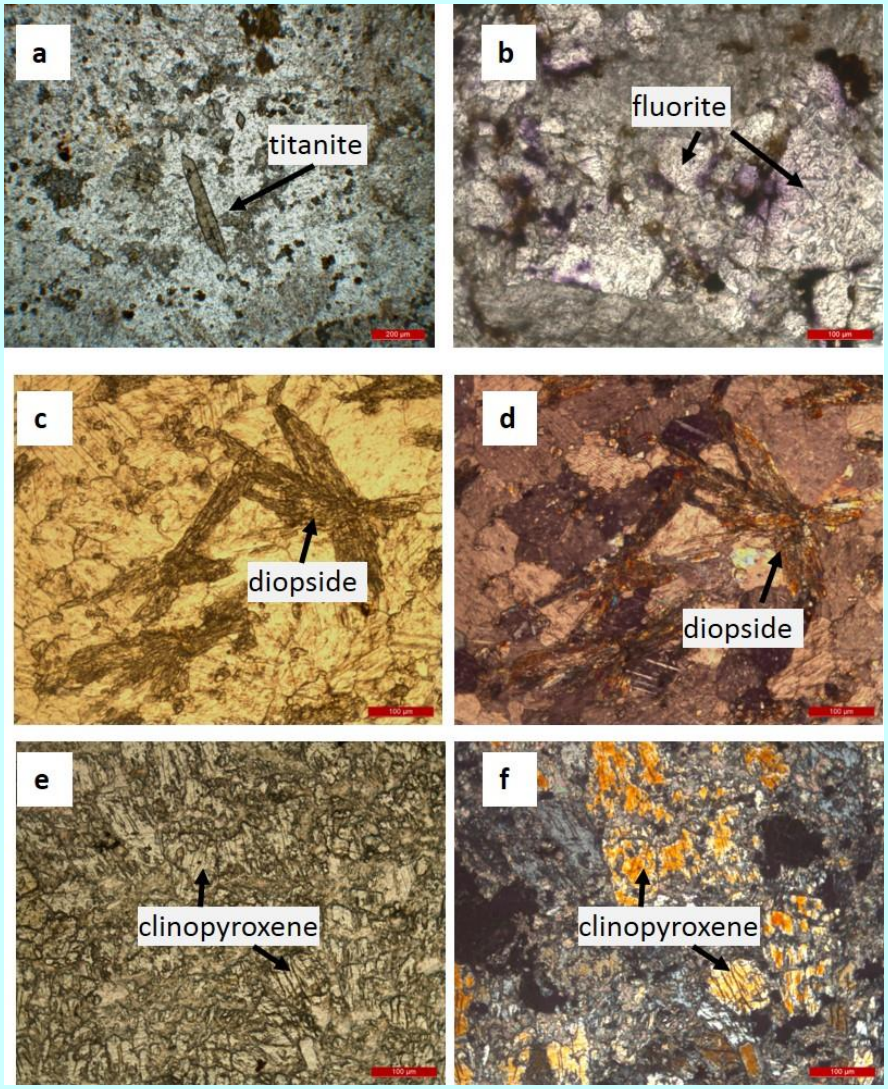

Figure 10.

Pale brown colored titanite appears as wedge-shaped and high relief in PPL (Figure 10a).
Fluorite which occurs with ore minerals, is white and partly purple with medium relief in PPL, whereas it is isotrop in XPL (Figure 10b).
Diopside with prismatic crystals is distinguished with inclined extinction, high relief, white to light green color in PPL (Figure 10c-d).
Pyroxene with two sets of cleavages is seen as pale green and high relief in PPL (Figure 10e), whereas, it has inclined extinction and high birefringence in XPL (Figure 10f).

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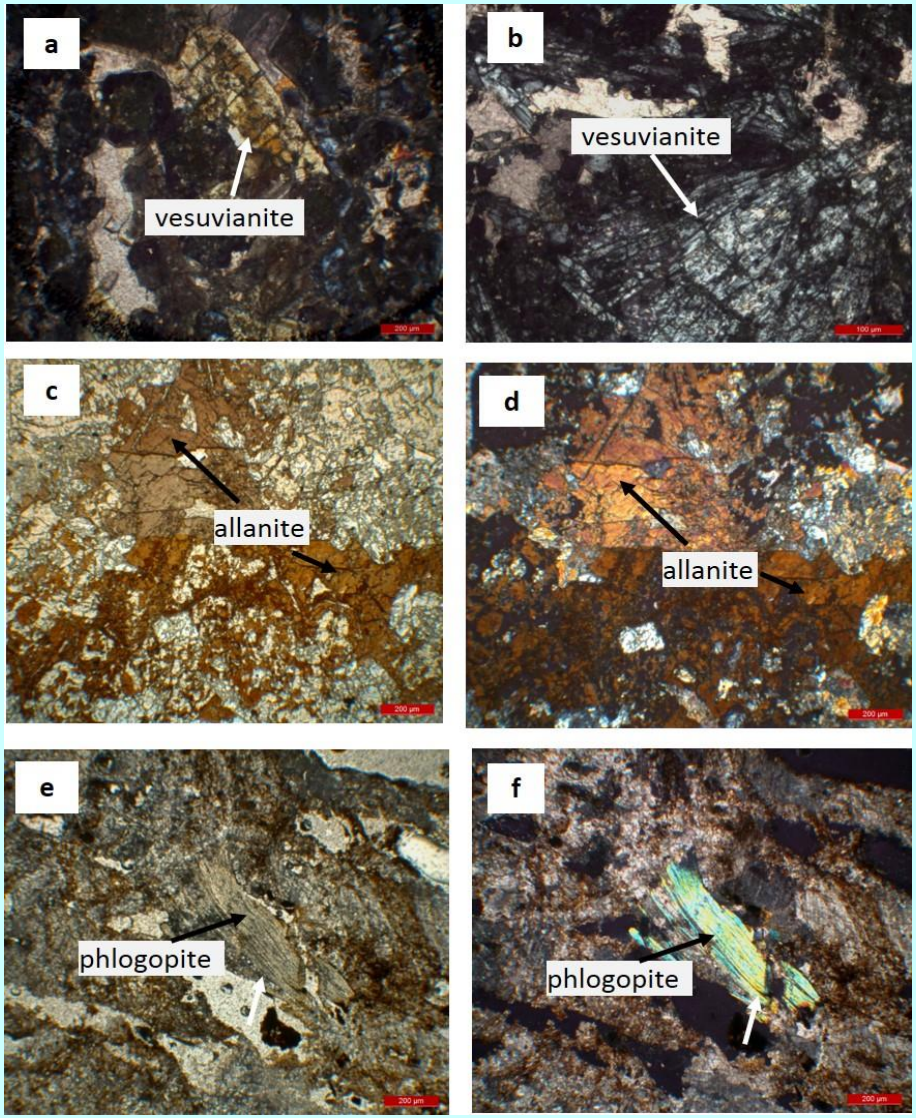

Figure 11.

Vesuvianite (idocrase) shows both euhedral tetragonal (Figure 11a) and prismatic crystals (Figure 11b) with 1st order gray and anomalous indigo blue in XPL.

Allanite, containing up to 20% REE, appears as red-brown strong paleochroism (Figure 11c) in PPL, medium-high birefringence in XPL (Figure 11d) and formed rounded to irregular shapes.

Phlogopite is determined one direction in cleavage, pale yellow and green color in PPL (Figure 11e), parallel extinction and third-order interference colors in XPL (Figure 11f).

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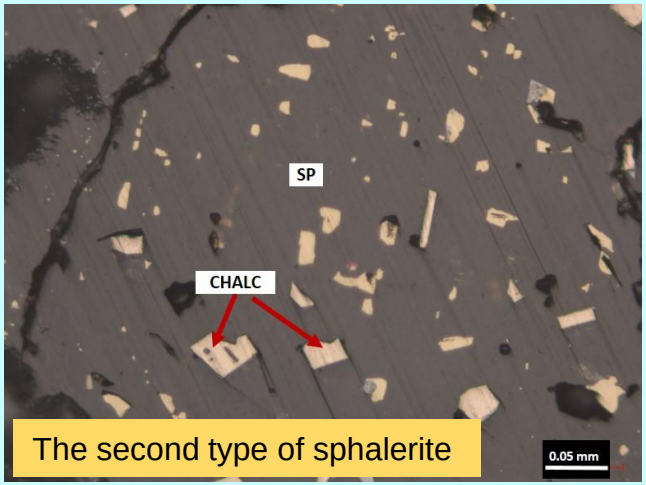
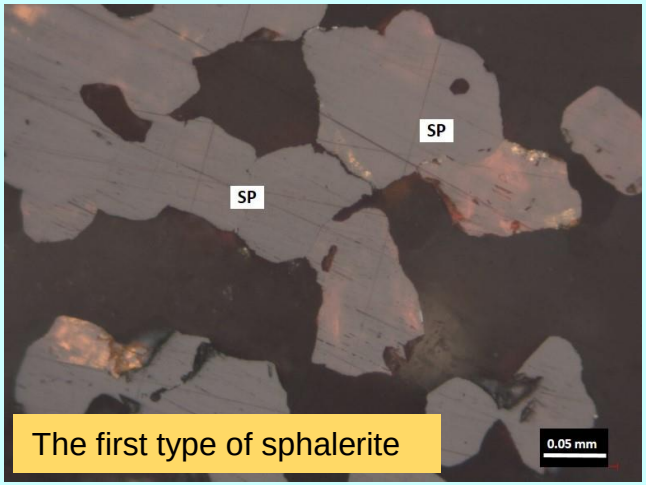
4. Ore Microscopy Studies

Ore minerals are sphalerite, galena, chalcopyrite, magnetite, hematite abundant pyrite and small amount of pyrrhotite, arsenopyrite, and manganese group minerals, native gold and fahlore, whereas gang minerals are garnet, pyroxene, fluorite, calcite, epidote, chlorite and quartz. Mineralization occurs as disseminated, vein and/or massive forms of variable grain sizes.



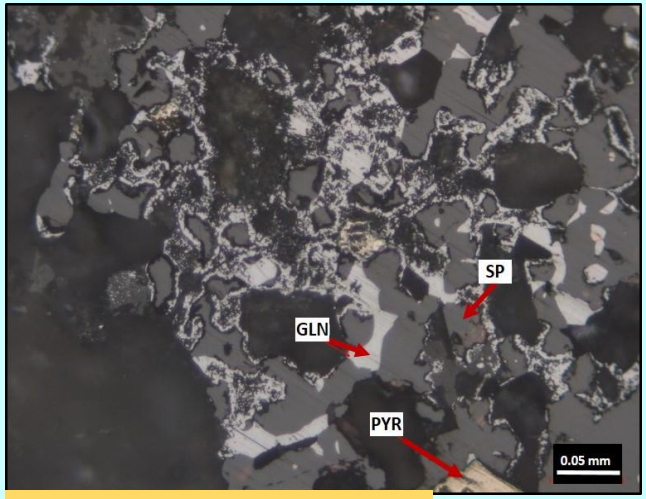
The second type of sphalerite



The first type of sphalerite

In ore microscopy, three types of sphalerite are distinguished:

- The first type sphalerite is medium-coarse grained and does not include any mineral.
- The second type sphalerite includes chalcopyrite inclusions and exsolutions.
- The third type of sphalerite is replaced by galena.



The third type of sphalerite

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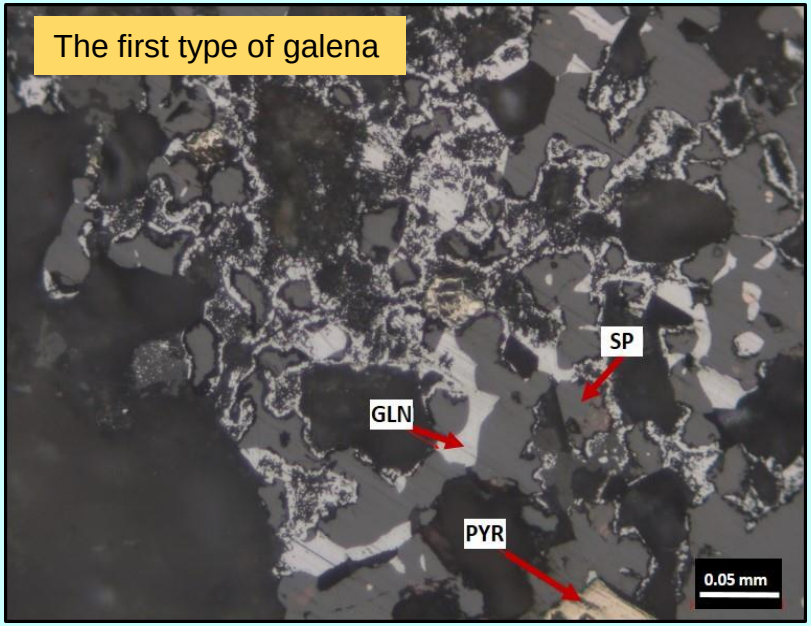

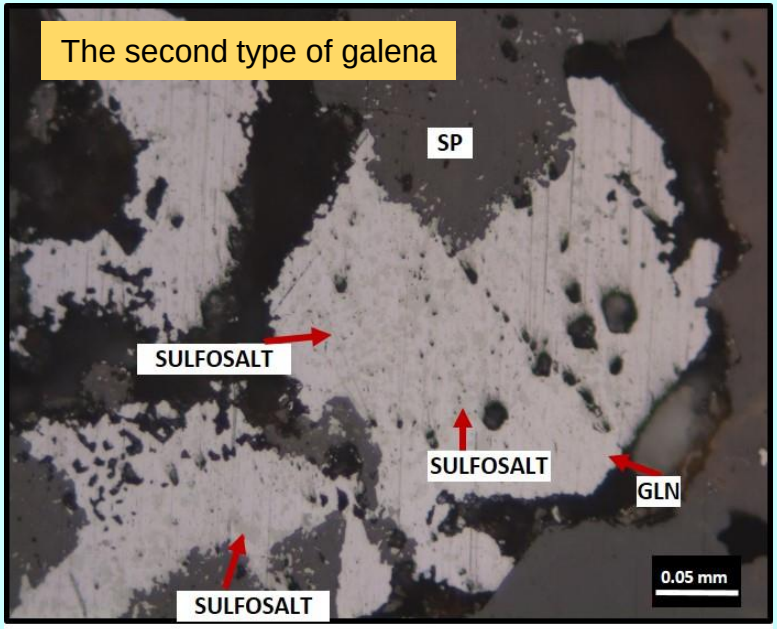

Two types of galena are determined:

- ✓ The first type galena settles down with sphalerite and forms anhedral and ambiguous mineral boundaries.
- ✓ The second type galena with anhedral and subhedral grains contains sulfosalts and fahlore mineral exsolutions.

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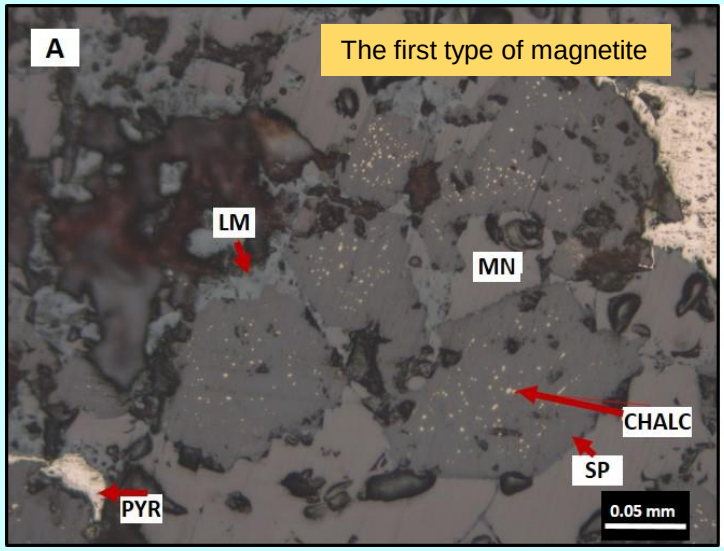

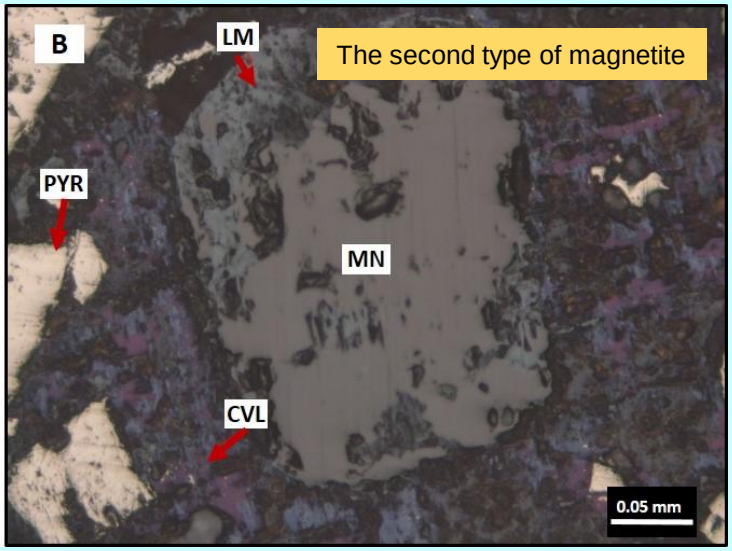

Two types of magnetites are distinguished:

- ✓ The first type magnetite grains include sphalerite containing chalcopyrite exsolutions. These magnetites are younger than sphalerite.
- ✓ The second type magnetite with anhedral grains partly or completely transforms to limonite. Some euhedral rombohedral magnetites have been martitized along their edges.

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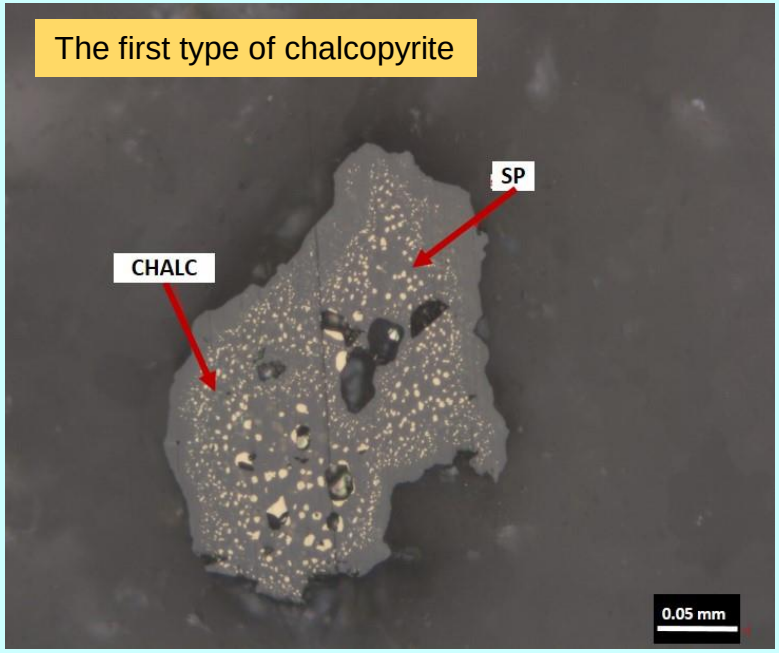

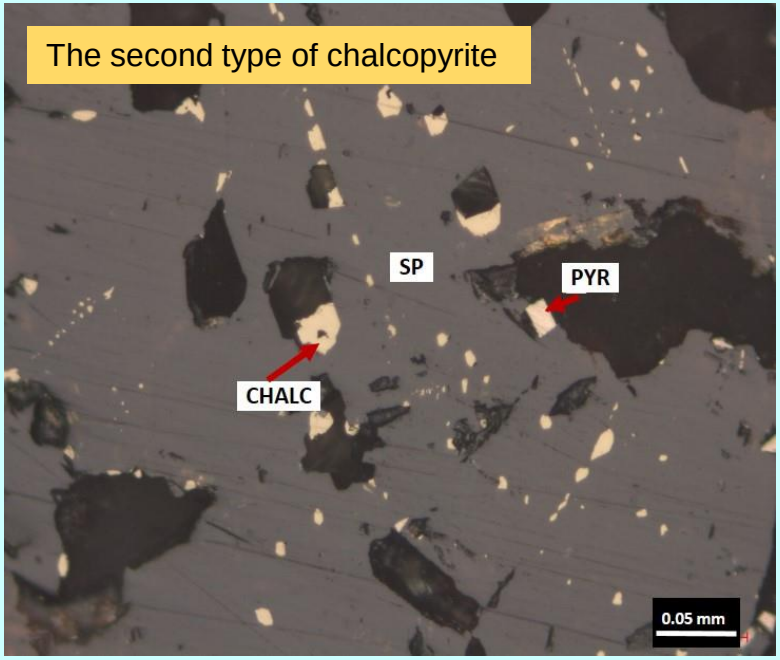

Two forms of chalcopyrite are determined:

- ✓ The first form of chalcopyrite drops are widely recognized in sphalerite. It is called «chalcopyrite disease» by Barton and Bethke (1987). These chalcopyrite grains formed like drops and sticks spread randomly.
- ✓ The second form chalcopyrite is formed as inclusions in sphalerite. In such samples, chalcopyrite grains are older than sphalerite.

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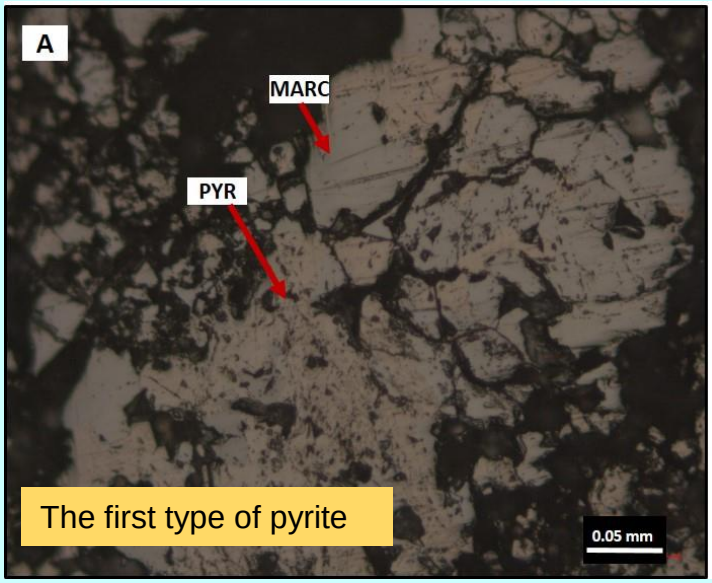

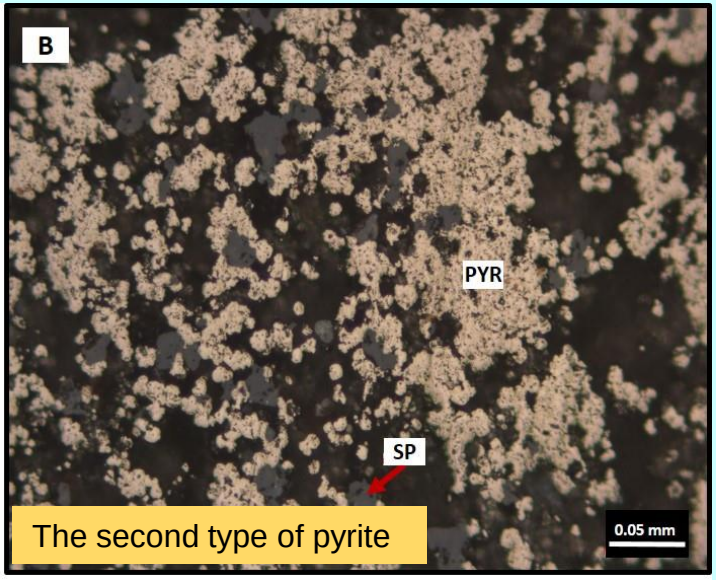

Two types of pyrite are observed:

- ✓ The first type pyrite is euhedral and subhedral coarse-grains with cataclastic texture. These pyrites transform to marcasite and appear with sphalerite, fahlore group minerals, magnetite and limonite.
- ✓ The second type pyrite is formed in framboidal, colloform texture.

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4. Conclusions

- The Keban Pb-Zn-(Cu) skarn deposit in the Elazig region, Turkey, was formed at the contact zone of the Permo-Triassic metamorphics and the Late Cretaceous plutonic rocks in the Eastern Taurus orogenic belt.
- The rock units in the region are partly hydrothermally altered graphite calc-schist containing crystallized limestone interlayers and lenses, meta-pellitic rocks (phylitte/calc-phyllite), dolomitic limestone, calc-silicate hornfels, marble and plutonic rocks.
- Results of mineralogical studies indicate that garnet and pyroxene-rich skarn formed in early (prograde) stage of skarnization whereas epidote, allanite, chlorite, tremolite, phlogopite, muscovite, calcite, quartz and fluorite are typical minerals of the retrograde stage.
- The endoskarn zone which is observed in a narrow zone in the area consists of plagioclase, pyroxene and garnet minerals, whilst the exoskarn zone includes garnet, pyroxene and vesuvianite minerals. Garnet in endoskarn is of andradite-grossular composition whereas those of distal exoskarn are composed of andradite type.
- Ore minerals are sphalerite, galena, chalcopyrite, magnetite, hematite abundant pyrite and small amount of pyrrhotite, arsenopyrite, manganese group minerals, native gold and fahlore, whereas gang minerals are fluorite, calcite, chlorite and quartz.
- Sphalerite is medium-coarse grained, semi-euhedral and contain chalcopyrite inclusions. Blebs of chalcopyrite are widely recognized in sphalerite (chalcopyrite disease). Galena replaces sphalerite and in some cases, it hosts several sulfo-salt minerals. Magnetite partly or completely transforms to limonite and chalcopyrite inclusions in sphalerite occur among the magnetite grains.